

sPHENIX Document Review Project Overview

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Brookhaven National Lab
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What is sPHENIX?

- sPHENIX is a major upgrade to the PHENIX detector. It is a large-acceptance, high-rate detector for Heavy Ion physics that repurposes **>\$20M** in existing PHENIX equipment, infrastructure and support facilities
- The detector is optimized to measure jet and heavy quark physics by incorporating a Tracker, full EM and Hadronic calorimeter coverage at $|\eta| < 1.1$, and a **1.5 T solenoidal magnetic field**.
- It will utilize much of the infrastructure already existing in the PHENIX detector complex and the **BaBar SC-magnet**. The Min Bias Trigger Detector is the reused **PHENIX Beam Beam Counter with upgraded electronics**.
- **A bottom-up resource-loaded project plan has sPHENIX assembled, commissioned and ready to take data in January 2022 based on CD schedule guidance from earlier this year.**

sPHENIX Collaboration Formed Dec 2015 Through Guidance by Berndt Mueller

- 10 Countries, 62 institutions, 235 collaborators & growing
- 3rd Collaboration Meeting @ GSU Dec 2016

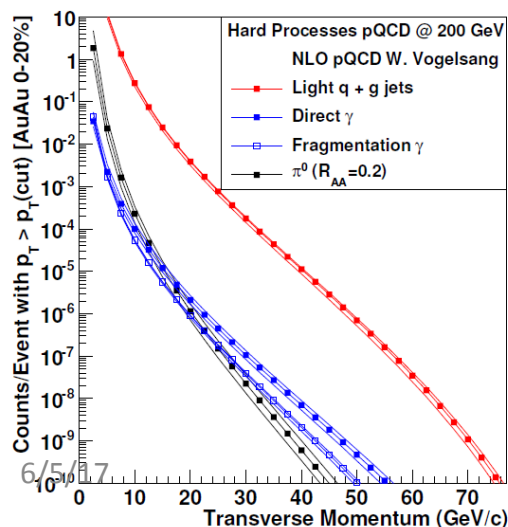
Abilene Christian University, Augustana University, Banaras Hindu University, Baruch College, Brookhaven National Laboratory, Chonbuk National University, Columbia University, Eötvös University, Florida State University, Georgia State University, Howard University, Institut de physique nucléaire d'Orsay, Institute for High Energy Physics-Protvino, Institute of Nuclear Research, Russian Academy of Sciences- Moscow Institute of Physics, University of Tsukuba, Iowa State University, Japan Atomic Energy Agency-JAEA, Joint Czech Group, Korea University, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Lehigh University, Los Alamos National Laboratory, Massachusetts Institute of Technology, Muhlenberg College, Nara Women's University, Kurchatov Institute, MEPhI, New Mexico State University, Ohio University, Petersburg Nuclear Physics Institute, RIKEN, RIKEN BNL Research Center, Rikkyo University, Rutgers University, Saint-Petersburg Polytechnic University, Stony Brook University, Temple University, Tokyo Institute of Technology, Universidad Técnica Federico Santa Maria, University of California, Berkeley, University of California, Davis, University of California, Los Angeles, University of California, Riverside, University of Colorado, University of Debrecen, University of Houston, University of Illinois-Urbana-Champaign, University of Jammu, University of Maryland, University of Michigan, University of New Mexico, University of Tennessee, University of Texas, Austin, University of Tokyo, Vanderbilt University, Wayne State University, Weizmann Institute, Wigner Research Center for Physics, Yale University, Yonsei University



The sPHENIX “Mission”

Excerpt from CD-0 Mission Need statement:

The DOE capability gap exists due to the lack of a detector at RHIC that has the capability to acquire the large samples of jets and heavy quarks needed to determine the properties of the exceptionally strongly interacting quark-gluon liquid discovered at RHIC and produced uniquely in the RHIC energy range. The detector capabilities required are a large solid angle, electromagnetic calorimetry, hadronic calorimetry, state of the art tracking and high rate capability. No such detector having all these capabilities currently exists at RHIC and no accelerator elsewhere in the world can compete with RHIC’s capabilities in this area. Heavy ion research at RHIC is currently performed by the collaborations using either the STAR (Solenoidal Tracker at RHIC) or PHENIX (Pioneering High Energy Nuclear Interaction eXperiment) detectors. The PHENIX detector is a high rate detector but is limited in solid angle and has no hadronic calorimetry. While the STAR detector has a large solid angle and state of the art tracking it is slow and lacks hadronic calorimetry. Thus the capability to carry out this world unique science does not exist and represents a gap in the DOE science mission.



22 weeks of Au+Au at RHIC

→ 100B MB events

→ 20B 0-20% events

Central Yields p_T Range

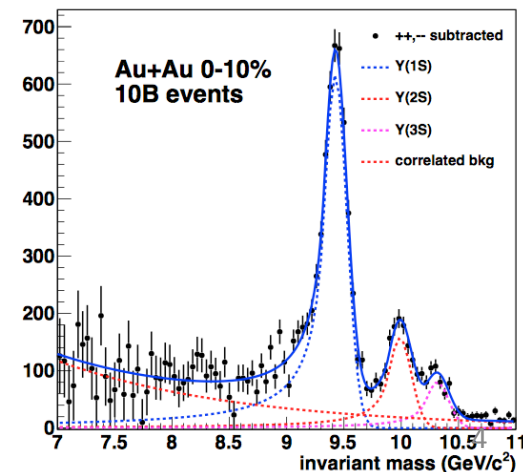
10^7 jets > 20 GeV/c

10^6 jets > 30 GeV/c

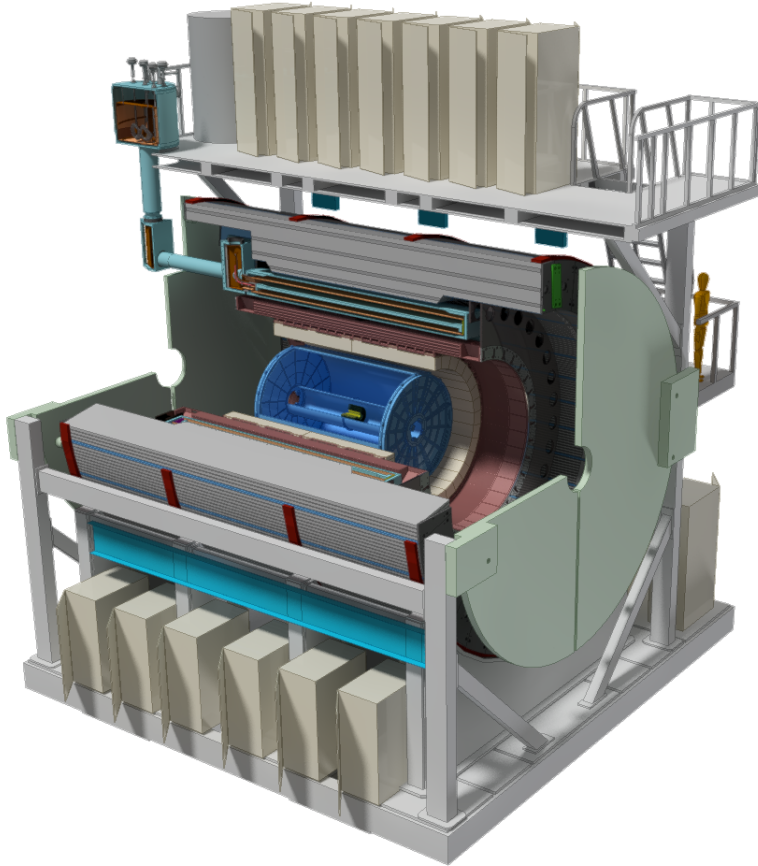
$10^4 \gamma_{\text{dir}}$ > 20 GeV/c

sPHENIX Document Review

$\Upsilon(1S,2S,3S)$



sPHENIX Conceptual Design



- Uniform fiducial acceptance $-1 < \eta < 1$ and $0 < \phi < 2\pi$
- Superconducting solenoid enabling high resolution tracking
- Hadronic calorimeter doubling as flux return
- Compact electromagnetic calorimeter to allowing fine segmentation at a small radius
- Solid state photodetectors that work in a magnetic field, have low cost, do not require high voltage
- Common readout electronics in the calorimeters
- High rate 15 kHz in AA allows for large unbiased MB data sample
- Utilization of existing PHENIX exp Infrastructure
- Compact TPC 250 μm hit res & continuous readout
- 4 Intermediate silicon strip tracking layers (Japanese funds)
- 3 layer – 2π MAPS-based vertex detector(Upgrade)

Most Detector components are at an advanced state of R&D

sPHENIX History

- sPHENIX Proposal submitted to DOE Fall 2012
- 1st DOE sPHENIX Science Review (Revisions requested) July 2014
- BaBar SC-magnet arrives at BNL Feb 2015
- 2nd DOE sPHENIX Science Review (All good. No recommendations) April 2015
- NPP Director's Cost and Schedule Review Nov 2015
- Formation of new sPHENIX Collaboration Dec 2015
- Tracker plan revised from all Si to TPC (SBU leads) Feb 2016
- DOE-ONP requests approach that would lower MIE costs Mar 2016
- Separating MIE from Ops Labor, Facility & Infrastr accepted by DOE Apr 2016
 - MIE is now just new scientific equipment appropriate for a PHENIX upgrade.
- MAPS(now MVTX) LDRD funded by LANL Jul 2016
- RIKEN commits to INTT (Si strip detector) Aug 2016
- Director's Review of sPHENIX Tracking system Sept 2016
- sPHENIX Granted CD-0 Mission Need Sept 2016
- sPHENIX OPC plan submitted to DOE Dec 2016
- LBNL, UC-Berkeley, Temple join sPHENIX(interest in MVTX, TPC) Dec 2016
- DOE authorization to start Conceptual Design Activities Feb 2017
- BNL Approves extraordinary Project rate for sPHENIX May 2017

sPHENIX MIE, Upgrade Support and Infrastructure & Facility Upgrade Plan

- The global sPHENIX upgrade has three components:
 - A. The **sPHENIX MIE** Upgrade covering the detector (Project Management, Tracker, EMCal, HCal, Calorimeter Electronics, DAQ/Trigger). Dominated by M&S costs. The MIE carries labor for Project Management.
 - B. The **Upgrade Support** is existing labor that works in support of the sPHENIX MIE upgrade. Eighty percent of the labor is the PHENIX technical support group in the Physics Dept and the remainder is a combination of CAD and SMD support staff. The Operations Support component is all labor.
 - C. An **Infrastructure and Facility Upgrade** of the 1008 complex . The Infrastructure and Facility Upgrade component is a combination of M&S and Labor. It is an upgrade of a 20 year old facility to modern standards to allow cryogenic operations in 1008 and provide a facility optimized for the operation of a modern detector.

The cost of each component of the effort is:

The MIE Cost range is 29-35M AY\$

The Upgrade Support is ~20M AY\$

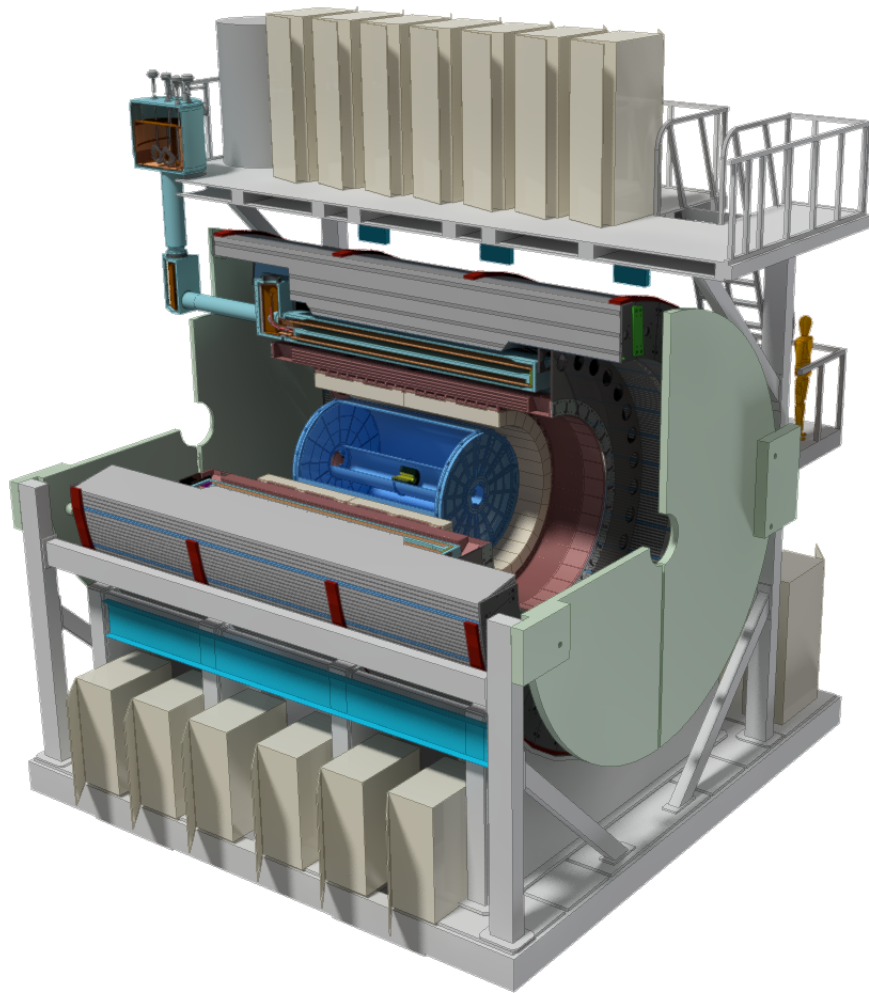
The Infrastructure and Facility Upgrade is ~\$20M AY\$

Structure of the MIE Project

- MIE consists of 6 sPHENIX Detector Subsystems plus Project Management: Time Projection Chamber, EMCal, HCal, Calorimeter Electronics, DAQ/Trig, Min Bias Det.
 - **The TPC, EMC, HCal and Calorimeter electronics are new devices and dominate the sPHENIX budget.**
 - **The MIE is funded by redirect RHIC Ops as directed by DOE-ONP.**
- The SC-Magnet (primarily cryo, PS and controls), Infrastructure, Installation and Integration are part of the 1008 Facilities upgrade and are not part of the MIE scope. Work is funded by redirected RHIC Ops.
- Lifting fixtures, trunk cables and fibers are part of Installation and Integration. Cables and fibers going between detector and patch panels or IR racks part of MIE.
- The electronics for the EMCal and HCal are located in the Calorimeter Electronics WBS category. The electronics for the TPC are located in the TPC WBS category.
- There are 2 Inner Si Tracker devices: INTT (Si strip) and MVTX (Si pixel). Both are off-project and NOT funded by redirected RHIC Ops.
 - **The INTT is funded by RIKEN**
 - **The MVTX will be a separate proposal to DOE as an upgrade project. It is a project where LANL/LBNL/MIT provides technical leadership with ~10 other institutions involved. The proposal is in preparation.**

Scope of sPHENIX MIE

The MIE Cost Range 30-35M AY\$ in Mission Need (CD-0) approval document



WBS sPHENIX MIE Project Elements

- | | |
|-----|-------------------------------|
| 1.1 | Project Management |
| 1.2 | Time Projection Chamber |
| 1.3 | Electromagnetic Calorimeter |
| 1.4 | Hadron Calorimeter |
| 1.5 | Calorimeter Electronics |
| 1.6 | DAQ-Trigger |
| 1.7 | Minimum Bias Trigger Detector |

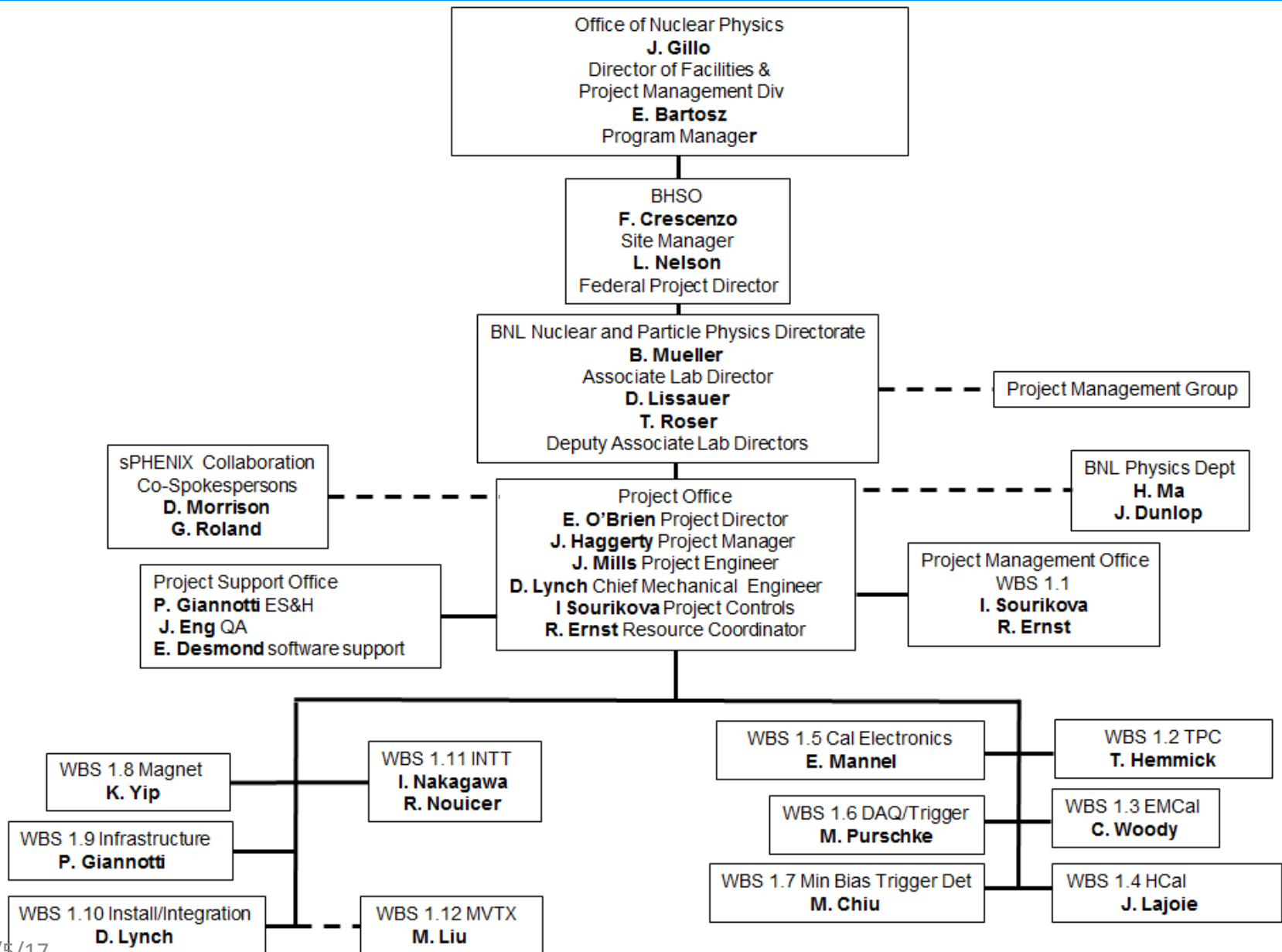
WBS Infrastructure & Facility Upgrade

- | | |
|------|--------------------------|
| 1.8 | SC-Magnet |
| 1.9 | Infrastructure |
| 1.10 | Installation-Integration |

WBS Parallel Activities

- | | |
|------|------------------------------------|
| 1.11 | Intermediate Silicon Strip Tracker |
| 1.12 | Monolithic Active Pixel Sensors |

Project Organization



L2 Managers and tentative Control Account Managers

L2 Managers:

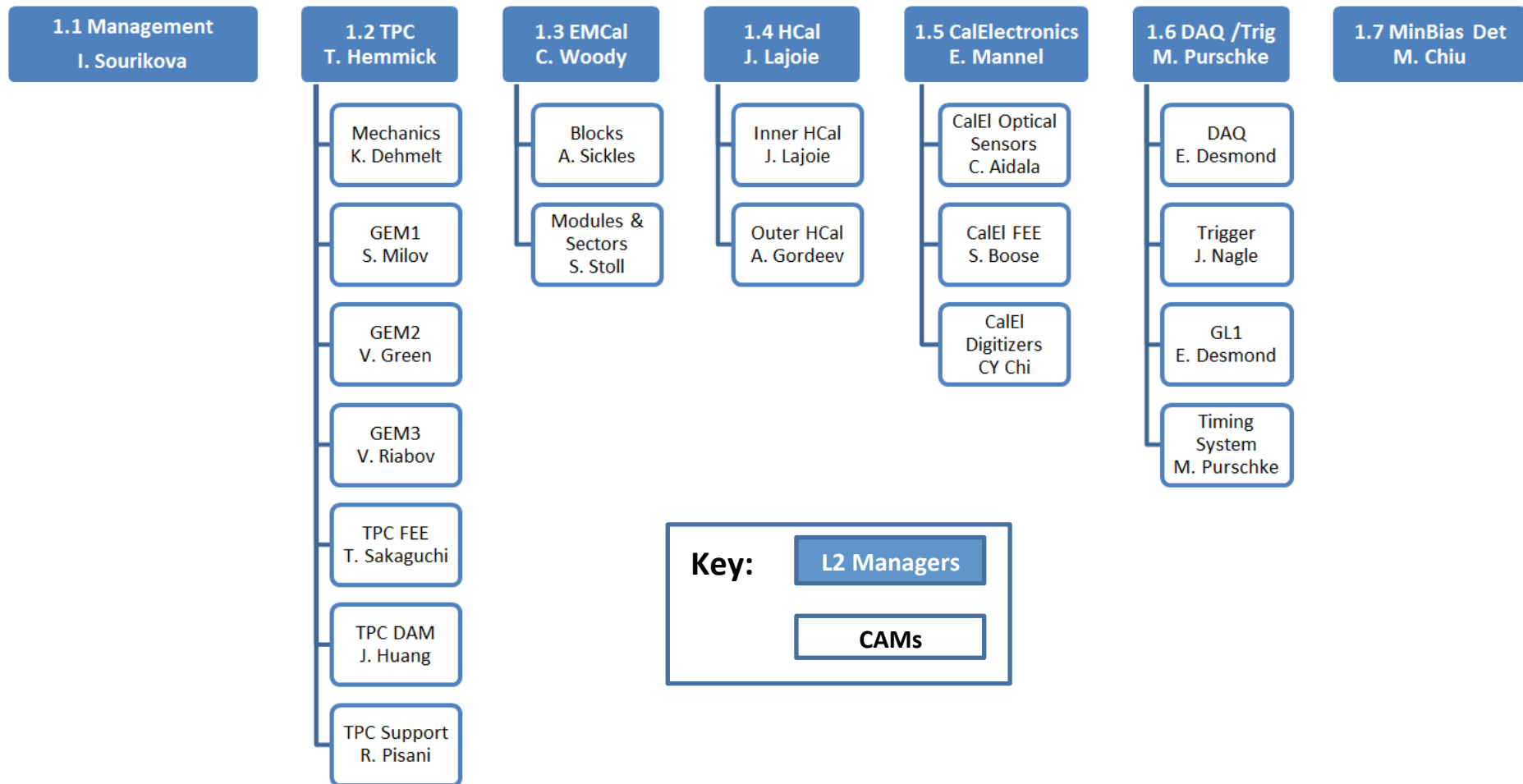
1.1 Project Management	Irina Sourikova(BNL-Project Controls)
1.2 TPC	Tom Hemmick (SBU)
1.3 EMCal	Craig Woody (BNL)
1.4 HCal	John Lajoie (ISU)
1.5 Calorimeter Electronics	Eric Mannel (BNL)
1.6 DAQ/Trigger	Martin Purschke (BNL)
1.7 Min Bias Trigger Detector	Mickey Chiu (BNL)

Control Account Managers

Project Managmt	Irina Sourikova (BNL)
TPC Detector	Klaus Dehmelt (SBU)
GEM r1	Sasha Milov (WIS)
GEM r2	Vicki Greene (Vandblt)
GEM r3	Victor Riabov (PNPI)
TPC FEE	Takao Sakaguchi (BNL)
TPC DAM	Jin Huang (BNL)
EMC Blocks	Anne Sickles (UIUC)
EMC Module/Sector	Sean Stoll (BNL)

Inner HCal	John Lajoie (ISU)
Outer HCal	Anatoli Gordeev (BNL)
CalE SiPMs	Christine Aidala (UM)
CalE Preamps	Steve Boose (BNL)
CalE Digitizer	CY Chi (Columbia)
DAQ	Ed Desmond (BNL)
Trigger	J. Nagle(UColorado)
Timing Sys	TBD (If necessary)
MB Trig Det	Mickey Chiu (BNL)

Add Slide Showing L2-CAM-WP Structure



sPHENIX Project Status

- We are finishing a bottom-up revision to the Resource-loaded schedule
 - 6 month effort of ~40 - 50 people.
 - 1800+ activities over 11 WBS L2 categories. All in MS-Project
 - The MIE Activities were integrated with the Magnet, Infrastructure, Installation/ integration.
 - We're in the process of merging the INTT with the rest of the project files
 - Consultant migrating the files to P6. Expect to be done by early July.
-
- Documents for the Jun 5-6 review: CDR, pPEP, WBS Dictionary, BOEs, prelim. Hazard Analysis Plan, Risk Registry, Risk Mitigation document, Security Vulnerability Assessment, Resource-loaded Schedule, Management Organization, Resource-loaded Schedule.
 - In process: Alternates Analysis Doc, Acquisition Strategy, Integrated Safety Management form

sPHENIX Subsystems

- **SC-Magnet** with a central field of 1.4-1.5 T
 - Will use former BaBar SC-Magnet. At BNL for testing
- **Outer HCal** steel + scin tile construction. It is both a $3.5 \lambda_I$ hadronic calorimeter and the magnet flux return.
- **Inner HCal** Stainless steel + scin tiles. Located between EMCal and solenoid.
- **EMCal** with SciFi embedded in a tungsten power-epoxy matrix.
- **Calorimeter electronics**: SiPMs, preamps, digitizer
- **Compact TPC**: Quad GEM readout modules (GEMs+ micromegas is an option)
 - Mechanics, Fee board (SAMPA-based), Data Aggregator (ATLAS FELIX-based)
- **4-layer Si strip layers** (RIKEN contribution)
- **3 layer MAPS** (Separate DOE upgrade proposal). Based on ALICE ITS.
- **DAQ/Trigger** system with new L1 Trigger-boards. Possible Timing system upgrade.
- **Min-Bias Trigger Detector**. Reuse of PHENIX Beam Beam counter
- **Support systems**: Gas, cooling, LV & HV power, controls, laser & pulser calibration, safety systems, support and access structures.

sPHENIX Schedule

Test Beam at FNAL(1 st round prototyping)	Feb 2016
CD-0	Sep 2016
Test Beam at FNAL(2 nd round prototyping)	Jan 2017
BNL Director's pre CD-1 Review	May-Jun 2017
OPA-CD-1/CD-3a Review	Nov 2017*
CD-1/CD-3a authorization	Dec 2017
Fabrication of long lead time components begins	Dec 2017
All Preproduction R&D and Design complete	Jun 2018
OPA- CD-2/CD-3b review	Jul 2018
CD-2/CD-3b authorization	Aug 2018
All fabrication begins	Aug 2018
sPHENIX installation begins in 1008 Facility	Apr 2020
sPHENIX Installed, cabled, ready to commission	Apr 2021
Initial commissioning complete	Jul 2022
First RHIC beam for sPHENIX	Jan 2022
CD-4 Approval	Jan 2023

***Subject to change pending FY18 Budget**

The Resource-loaded Schedule contains 8 months of float to Jan 2022

CD-1 Review Document Status

1. Integrated Project Team- **Complete**
 2. WBS (WBS Dictionary)- **Updated**
 3. Cost Books-Basis of Estimate
 4. Contingency Risk/Analysis
 5. Activity List & Activity Attributes
 6. Project Schedule
 7. Critical Milestones
 8. Proposed Funding Profile
 9. Proposed Labor Profile
 10. Preliminary Hazard Analysis Report- **Initial Release**
 11. NEPA form- **Complete**
 12. Integrated Safety Management Plan- **In Development**
 13. Conceptual Design/Conceptual Design Report- **Advanced Design/ Advanced Draft**
 14. Acquisition Strategy- **In Development**
 15. Close all previous review recommendations- **Ongoing**
 16. Preliminary Project Execution Plan- **Initial Release**
 17. Preliminary Risk Management Plan- **Initial Release**
 18. Preliminary Risk Assessment and Risk Registry- **Advanced Draft**
 19. Preliminary Security Vulnerability Assessment (Short security equipment protection & cyber security)- **Complete**
 20. Alternate Analysis- For the PEP includes scientific alternatives- **In Development**
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- sPHENIX L2, CAMs, Project Office, and Engineers have been working on this for the past 6 months. All derived from WBS MS-Project file- **(Updated)**
- Integrated Safety, ESH
- Risk Management

Major Project Milestones

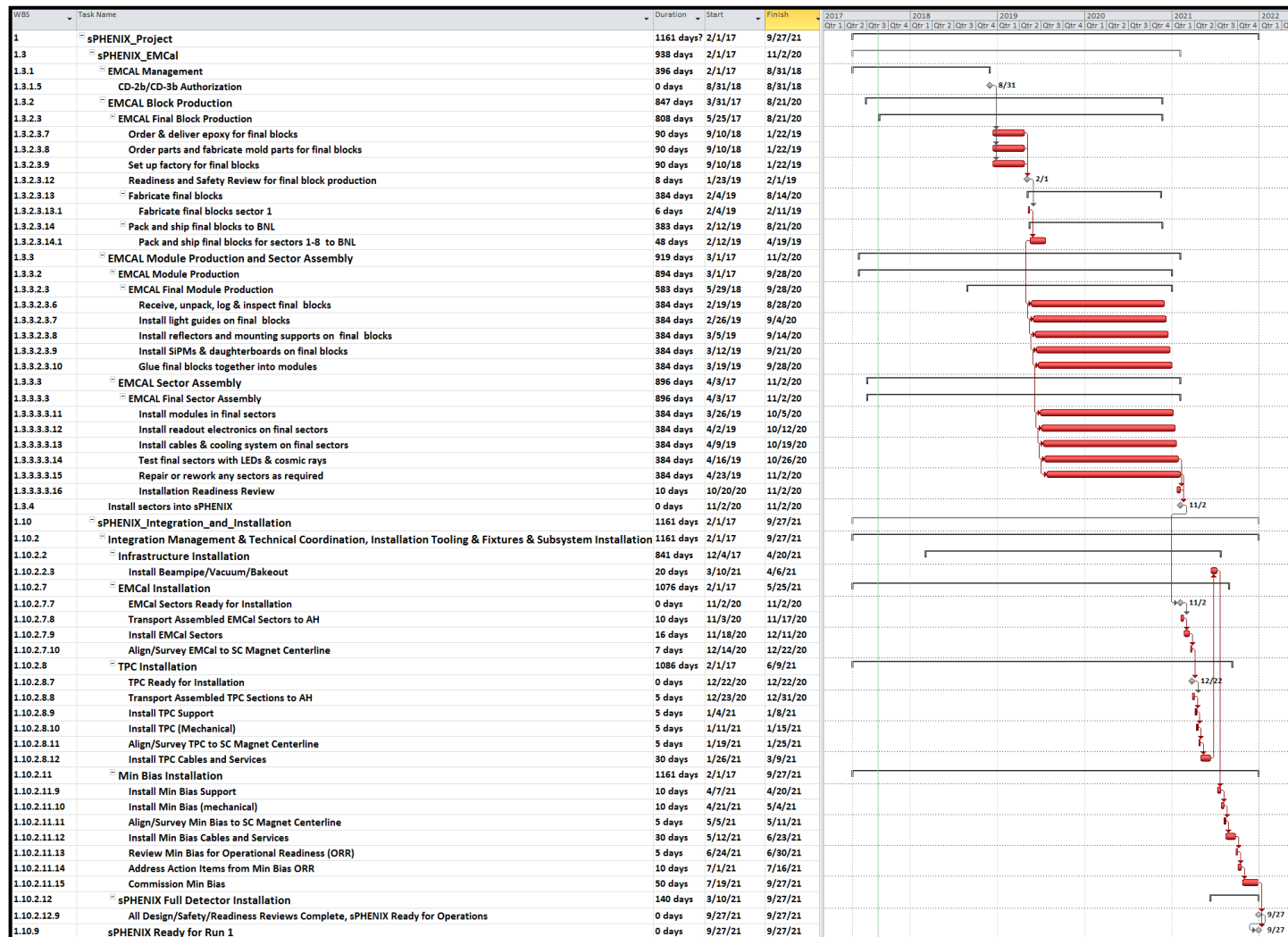
WBS	Project Milestone	Scheduled Dates
1.2.2	Quad GEM Module Readiness review	6/2018
1.2.2/3/4	Quad GEM Module Production complete	6/2019
1.2.5	TPC FEE Production Readiness review	5/2018
1.2.5	TPC FEE Production complete	7/2019
1.2.6	TPC DAM Production Readiness review	6/2018
1.2.6	TPC DAM Production complete	9/2019
1.3.2	Block Production Readiness review	1/2019
1.3.3	Module and Sector Production Readiness review	8/2018
1.3.4	Install EMCal sectors into sPHENIX	11/2020
1.4.2	Procurement of IHCAL mechanical structure complete	4/2020
1.4.2	Procurement of IHCAL scin tiles complete	10/2019
1.4.3	Procurement of OHCAL scin tiles complete	3/2019
1.4.3	First sector OHCAL available for installation	9/2019
1.4.3	Last sector OHCAL available for installation	4/2020
1.5.1	Optical Sensor Procurement Complete	9/2019
1.5.2	EMCAL Fee Production Complete	2/2020
1.5.2	HCAL Fee Production Complete	10/2019
1.5.3	Calorimeter Digitizer Production start	8/2018
1.5.3	Calorimeter Digitizer Production Complete	10/2019
1.6	DAQ Ready for Operation	10/2020
1.7.3	Receive Digitizers for Min Bias Det	4/2019
1.7.4	Min Bias Det ready for installation	12/2019

Table 1: Major CD milestones of the sPHENIX project.

Critical Path

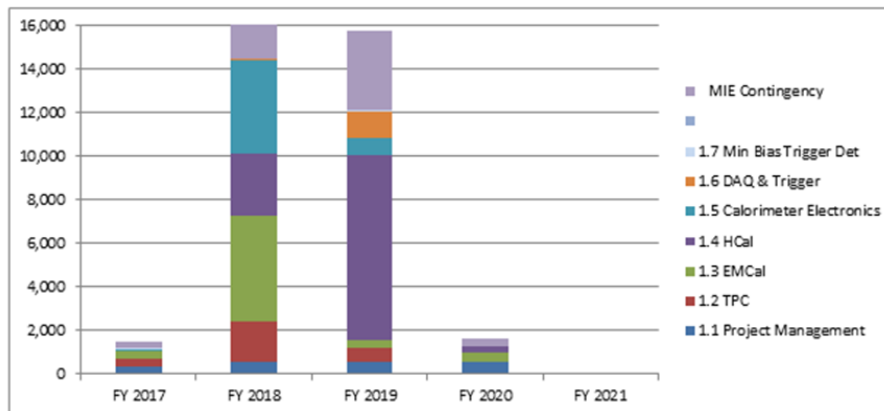
Project Schedule:

- The EMCal is on the critical path driven by production time for 6100 2x2 towers.
 - The EMCal and associated calorimeter electronics are the technical scope of the project
- The Inner HCal is behind the EMCals's critical path by only a few months.



Cost Profile in AY\$ and Cost Drivers

Baseline Scenario
AY k\$'s - with Extraordinary Construction Overhead Application



Cost Drivers:

OHCaI steel \$5.3M

EMCaI W-powder \$2.2M

EMCaI scint fibers \$1.4M

Cal digitizing elec. \$1.9M

HCal scint tiles \$1.8M

TPC Fee board \$0.9M

SiPMs \$1.0M

Baseline Scenario
AY k\$'s - with Extraordinary Construction Overhead Application

WBS	SYSTEM	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	Total
1.1	Project Management	342	528	537	555	8	1,970
1.2	TPC	334	1,867	662	0	0	2,863
1.3	EMCaI	360	4,909	346	406	0	6,021
1.4	HCal	15	2,811	8,512	315	0	11,653
1.5	Calorimeter Electronics	52	4,326	757	0	0	5,135
1.6	DAQ & Trigger	0	32	1,267	0	0	1,299
1.7	Min Bias Trigger Det	64	0	72	0	0	136
Baseline Total		1,167	14,473	12,153	1,276	8	29,077
MIE Contingency		319	4,291	3,594	329	2	8,535
MIE Total		1486	18764	15747	1605	10	37612

WBS	SYSTEM	Baseline	Contingency	Total
1.1	Project Management	1,970	394	2,364
1.2	TPC	2,863	868	3,731
1.3	EMCaI	6,021	1806	7,827
1.4	HCal	11,653	3496	15,149
1.5	Calorimeter Electronics	5,135	1541	6,676
1.6	DAQ & Trigger	1,299	390	1,689
1.7	Min Bias Trigger Det	136	41	177
MIE Totals		29,077	8535	37,612

Next steps are profile smoothing and descope to fit within BNL guidance

Long Lead-Time Items for CD-3a

SiPMs for EMCal and HCal	\$1.0M
Outer HCal Steel	\$5.3M
Scintillating Tiles for HCal	\$1.8M
Scintillating Fibers for EMCal	\$0.7M

**Each have a long production time, long queue time or both.
All are for detectors on or near the critical path.**

Proposed Preliminary Key Performance Parameters

System	Parameters	Preliminary KPP's
Time Projection Chamber	Operations	90% live channels based on laser, pulser, cosmics
Time Projection Chamber	Pointing resolution	250 microns to vertex using cosmics
Electromagnetic Calorimeter	Operations	90% live channels based on LED, cosmics
Hadronic Calorimeter	Operations	90% live channels based on LED, cosmics
Hadronic and EM Calorimeter	Operations	On average mip peak spread 30% FWHM
Min Bias Trigger Detector	Operations	90% live channels based on laser. 50 ps/ch timing resolution w/ Bench Test
DAQ/Trigger	Event rate	10 kHz with pulser
DAQ/Trigger	Data Logging rate	10 GBit/s with pulser

Oversight and Project Meetings

Oversight

- Biweekly sPHENIX meeting with DOE BHSO
- Monthly sPHENIX meeting with DOE-ONP
- Monthly PHENIX R&R(decommissioning) meeting with DOE-ONP
- Biweekly meeting with BNL ALD's Project Management Group
- 8 internal BNL reviews of the subsystems
- 2 BNL Director's reviews with external committees.

Project Meetings

- Weekly Management meeting
- Biweekly meetings for each MIE subsystems
- Biweekly meetings for SC-magnet
- Biweekly sPHENIX engineering meeting
- Biweekly simulations meeting
- Biweekly Tracking meeting
- Monthly L2 Managers meeting (frequency to increase to biweekly)

In addition there is a biweekly General Meeting for the whole collaboration at which the Project reports and a biannual Collaboration meeting.

We've held 800 sPHENIX meetings over the last 3 years.

Summary

- sPHENIX is a major upgrade to the PHENIX experiment that will utilize >\$20M in existing equipment. The sPHENIX scientific collaboration is a new organization that was formed 1.5 years ago.
- The sPHENIX Project team is established and has been working together for 2.5 years.
 - **The Project Organization including L2's and CAMs is set.**
- There is a newly revised Resource-loaded schedule with a bottom-up cost and contingency estimate.
 - **We are still debugging some aspects of it including the resource allocations.**
 - **Bottom-up cost estimate exceeds BNL guidance. We'll work with the collaboration and BNL to bring the scope within bounds**
- We have releases or advanced draft of most of the documents for required for CD-1 including a CDR(300 pages, 200 figures) and a pPEP.
 - **They are available on the review web site.**
- Project schedule exists that has the Project complete by Jan 2022 with 8 months float.
 - **The FY18 Budget reality will almost certainly cause a schedule delay. It is too early to determine the schedule impact.**

Back Up

Labor Profile by Job Category for MIE Support

Row Labels	Sum of FY 17 FTE	Sum of FY 18 FTE	Sum of FY 19 FTE	Sum of FY 20 FTE	Sum of FY 21 FTE	Totals
CAT B	8.79	12.54	26.89	27.67	0.53	76.43
Administrative	0.32	0.49	0.48	0.48	0.01	1.77
Professional	4.01	5.88	7.71	5.66	0.06	23.32
Purchased Services	0.00	0.27	0.38	0.13	0.00	0.78
Scientific	2.15	2.67	2.84	2.13	0.16	9.95
Technical	2.31	3.23	15.49	19.27	0.31	40.61
Contributed	2.03	11.45	40.72	9.96	6.23	70.40
Professional	0.00	1.00	0.00	0.00	0.00	1.00
Postdoc	0.00	0.73	2.34	3.09	0.00	6.16
Scientific	0.94	2.00	4.52	0.18	0.00	7.64
Student	1.10	7.72	28.41	6.69	6.23	50.15
Technical	0.00	0.00	5.45	0.00	0.00	5.45
Grand Total	10.83	23.99	67.61	37.63	6.77	146.83

Does not show 7 FTE/yr Scientific Support from the BNL PHENIX Group